



Seismic Methods Used To Check Strength of Concrete Runway Reconstruction

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Conference**

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Project Description

- **Client has requested that Airport name not be used due to some outstanding close-out issues**
- **This presentation is about the technology used to identify strength of PCC**
- **Project was to remove and replace a Concrete Runway**
- **Small hub air carrier airport, runway over 10,000', in 2006**



Problem with PCC Strength

- **During construction, concrete appearance changed**
- **Very dark color and no typical concrete smell**
- **Contractor continued paving that day**
- **Next day, joint sawing spalled badly, core collapsed**
- **Paving stopped until problem identified and corrected**



Problem Concrete Removed





Problem Identified and Corrected

- **Quickly determined excess fly ash in mix**
- **Cement silo had fly ash in it, was emptied**
- **Contractor investigated found SAME leased trucks used for cement and fly ash, weren't cleaned out**
- **Started paving again**
- **Problem happened again within 2 weeks**
- **Contractor installed colored flanges to silos**
- **Truck driver had to check out proper flange from superintendent to unload**



Colored Flanges





Contaminated PCC Removed

- **PCC removed that was clearly visually contaminated**
- **Difficult to identify the exact location of start of contamination**
- **Removal progressed all directions until visually “sound” PCC found**
- **Contractor immediately replaced all of the removed PCC**
- **Lingering doubts if PCC left contained more that 30% fly ash in mix design**



Concrete Core, Top Excess Fly Ash



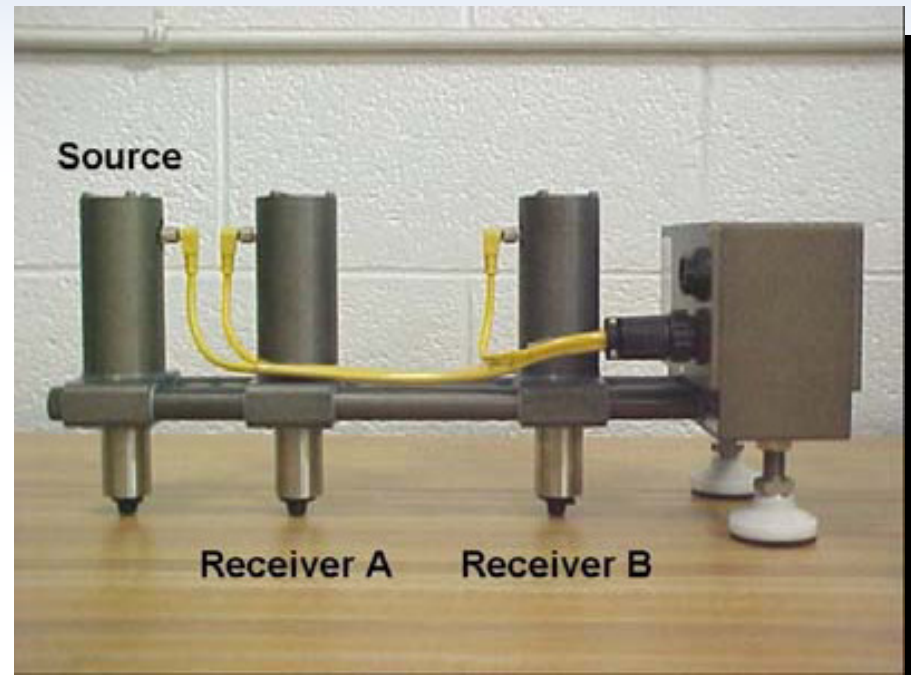


Verification Process

- **Evaluated coring, would have required too many to be effective**
- **Relatively new non-destructive testing using seismic methods**
- **Research funded by IPRF, Report in 2006**
- **Principal investigator Dr. Soheil Nazarian, Univ of TX, El Paso**
- **Portable Seismic Pavement Analyzer (PSPA)**



PSPA Instrumentation



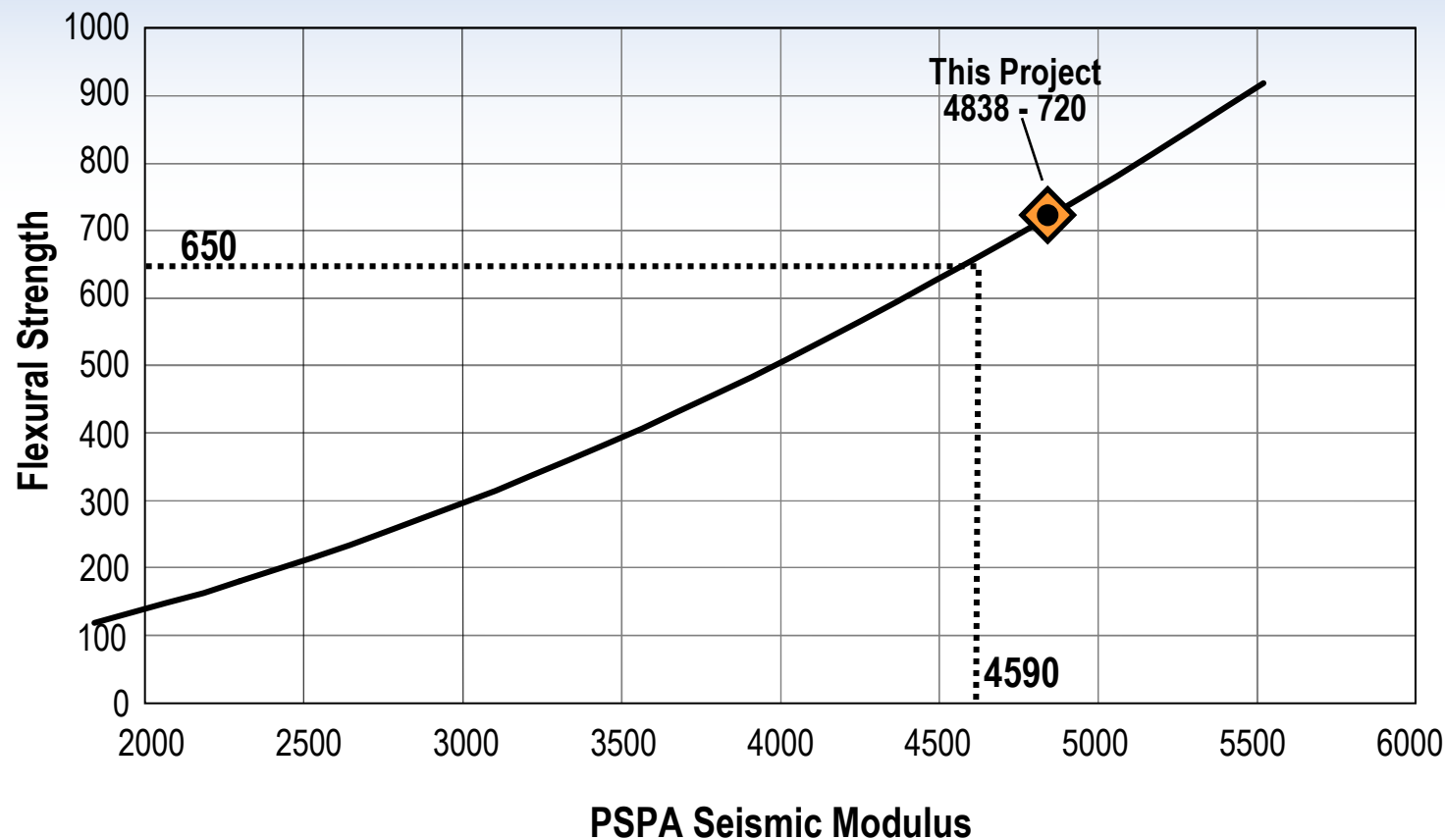


PSPA Definition

- **Generation, detection & measurement of velocity of elastic waves within a medium**
- **Measured velocity converted to modulus of elasticity (seismic modulus)**
- **In the field impact pavement surface with source & monitor with receiver**
- **Direct relationship between seismic modulus and PCC strength**



Typical Relationship Seismic Modulus and Strength





Typical PSPA Process

- **Prepare PCC specimen (cylinder or beam)**
- **Seismic modulus test of specimen in lab**
- **Test strength of specimen**
- **Results give relationship**
- **Seismic modulus with PSPA from existing pavement in field**
- **Correlation of seismic modulus values between specimen and field**
- **Estimate pavement strength in the field**

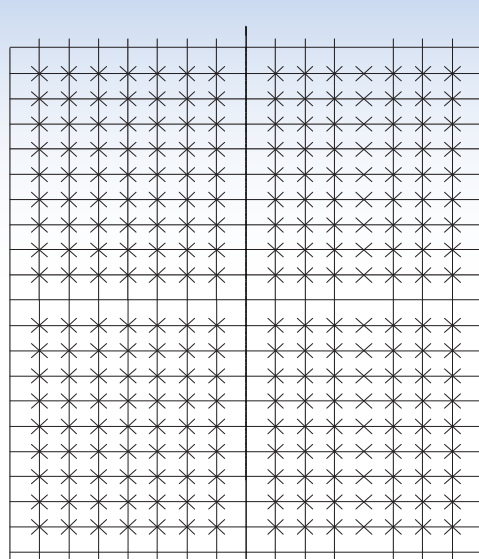


This Project Modified Process

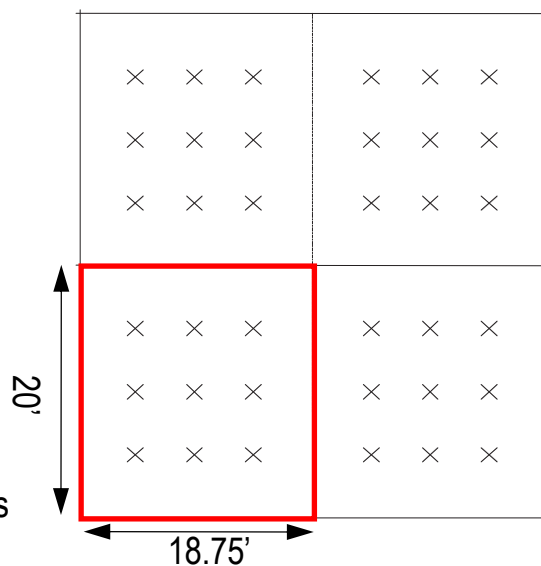
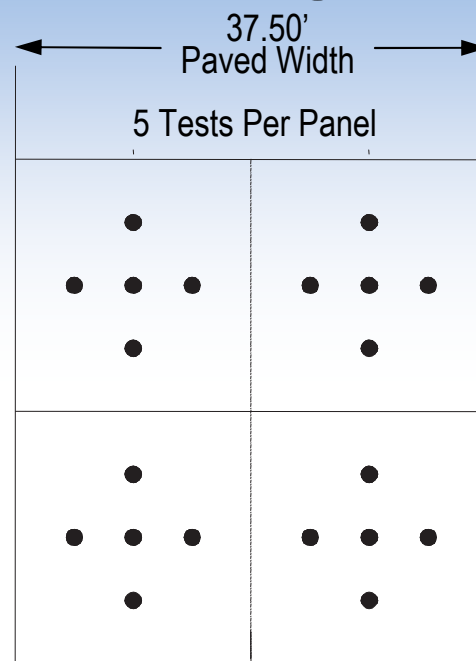
- **Paving complete, so no PCC mix available**
- **Established baseline modulus from existing PCC in-place that was acceptable (instead of from lab)**
- **Modulus of existing thickness cores, taken earlier, to compare to baseline**
- **Then modulus from pavement areas in question**
- **Correlation of baseline to cores and then baseline to questionable PCC**
- **Determine if questionable PCC strength is acceptable**
- **Evaluated number of test per panel, 9 selected**



PSPA Possible Testing Locations

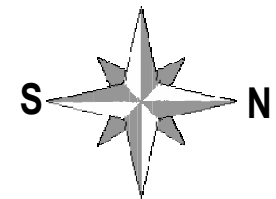
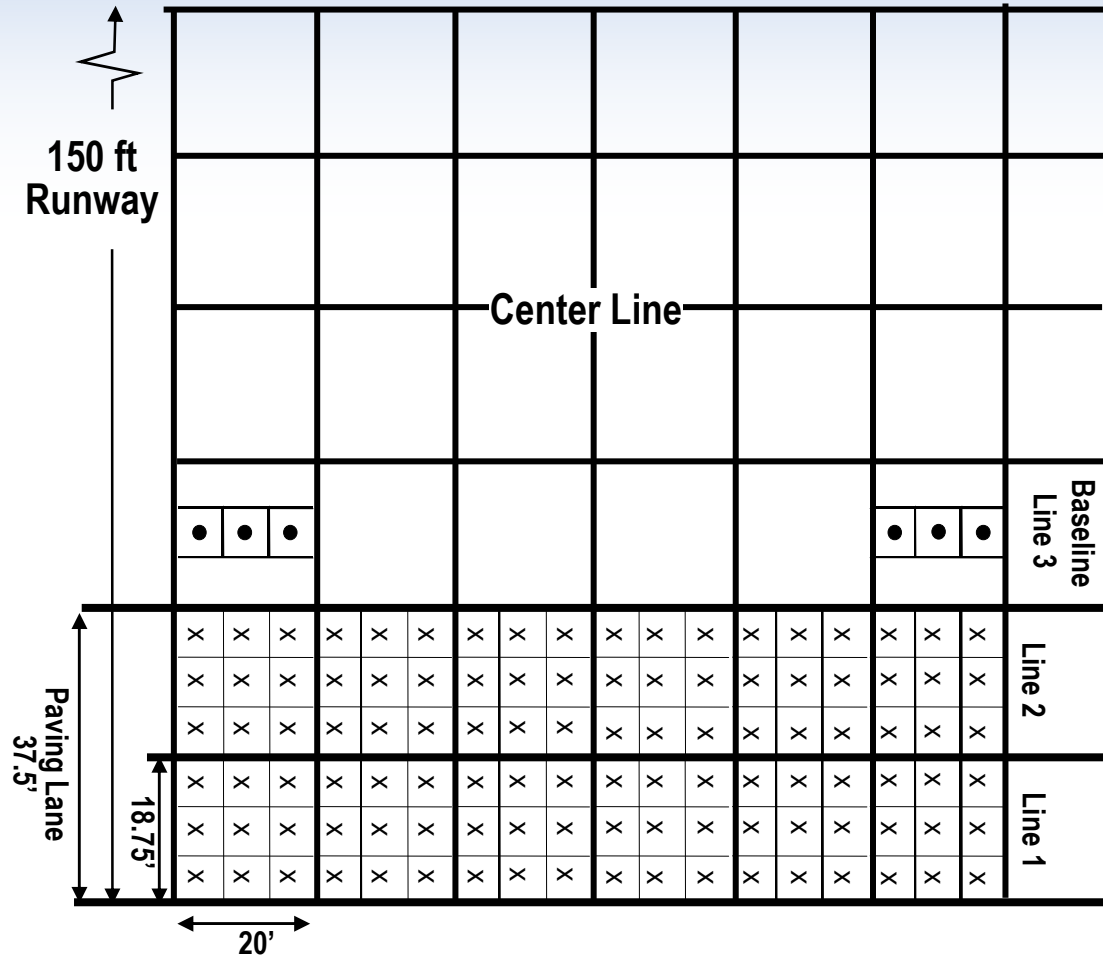


56 Tests Per Panel (2')





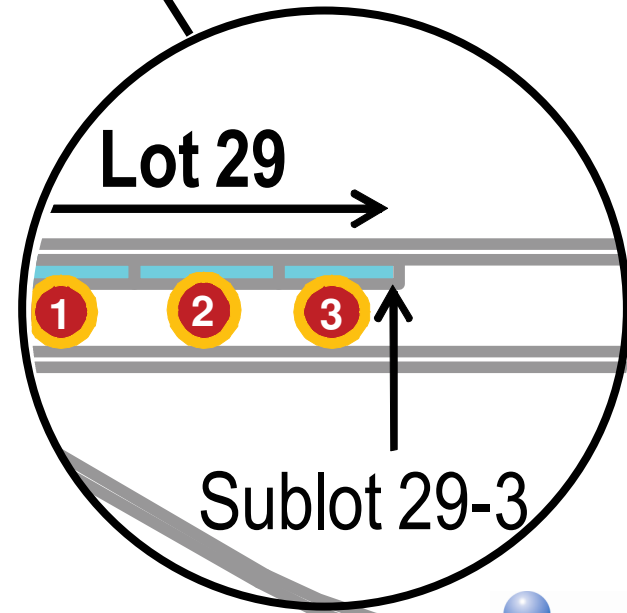
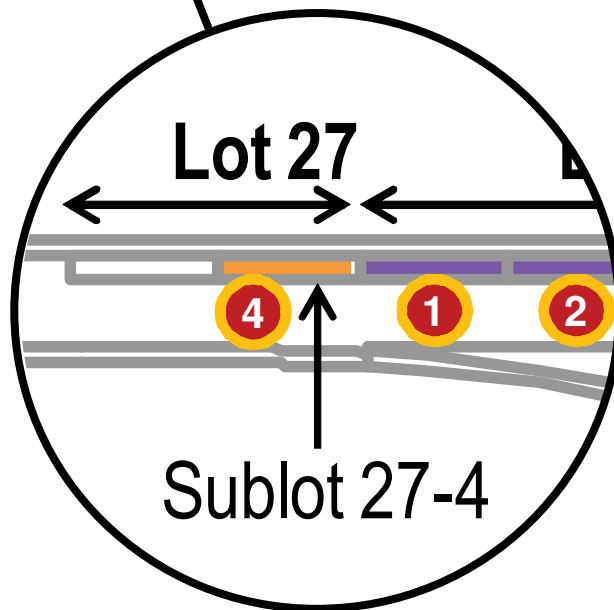
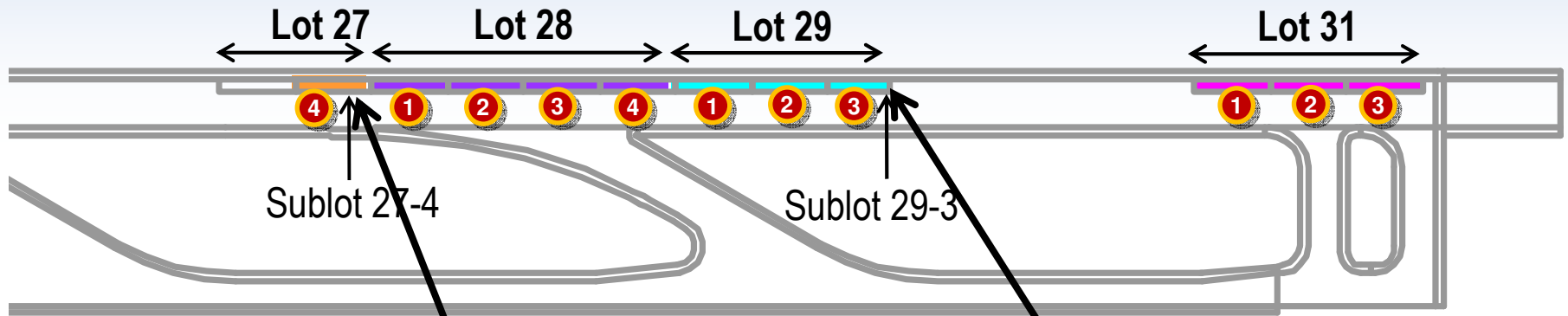
Schematic of PSPA (Control) Field Tests



x Questionable PCC
• Baseline PCC



4 Lots and 11 Sublots That Were Tested



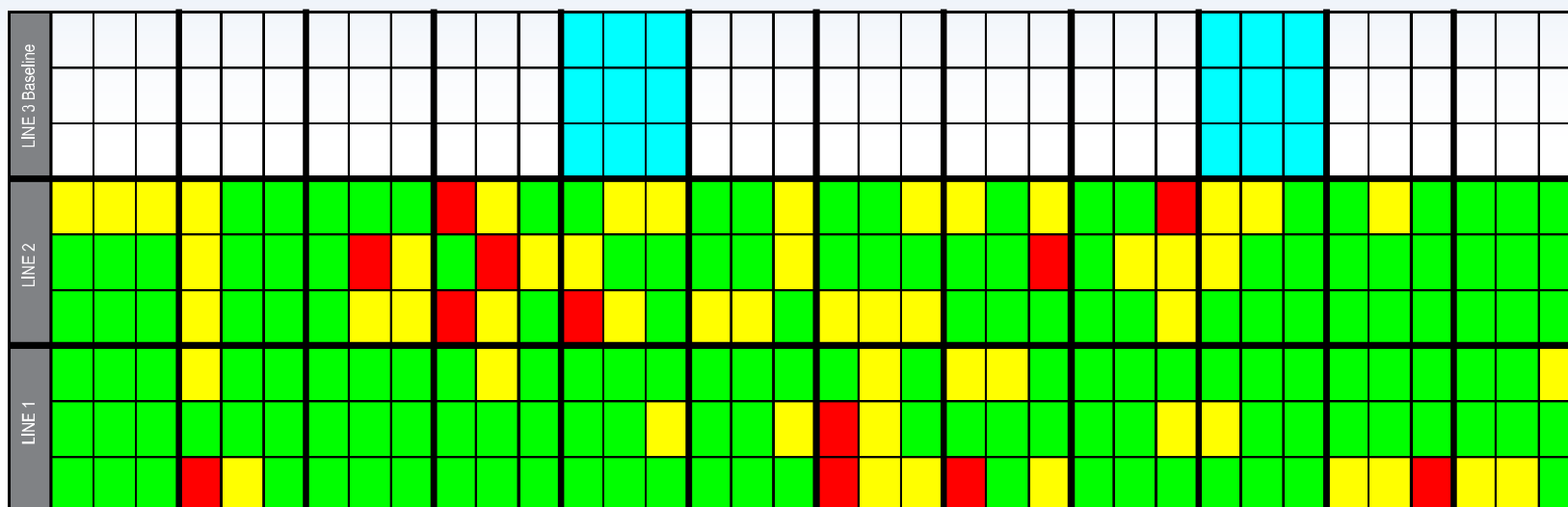


Results of PSPA Testing

Color Code	Result
Green	Measured modulus is similar or higher than baseline modulus
Yellow	Measured modulus is somewhat less than baseline modulus
Red	Measured modulus is substantially less than baseline modulus
Purple	Panels Removed and Replaced by Visual Inspection
Blue	Baseline Panels - Acceptable



Sublot 27-4



- Measured modulus is similar or higher than baseline modulus
- Measured modulus is somewhat less than baseline modulus
- Measured modulus is substantially less than baseline modulus
- Panels Removed and Replaced By Visual Inspection
- Baseline Panels (Control) - Acceptable

Panels (18.75'x 20')

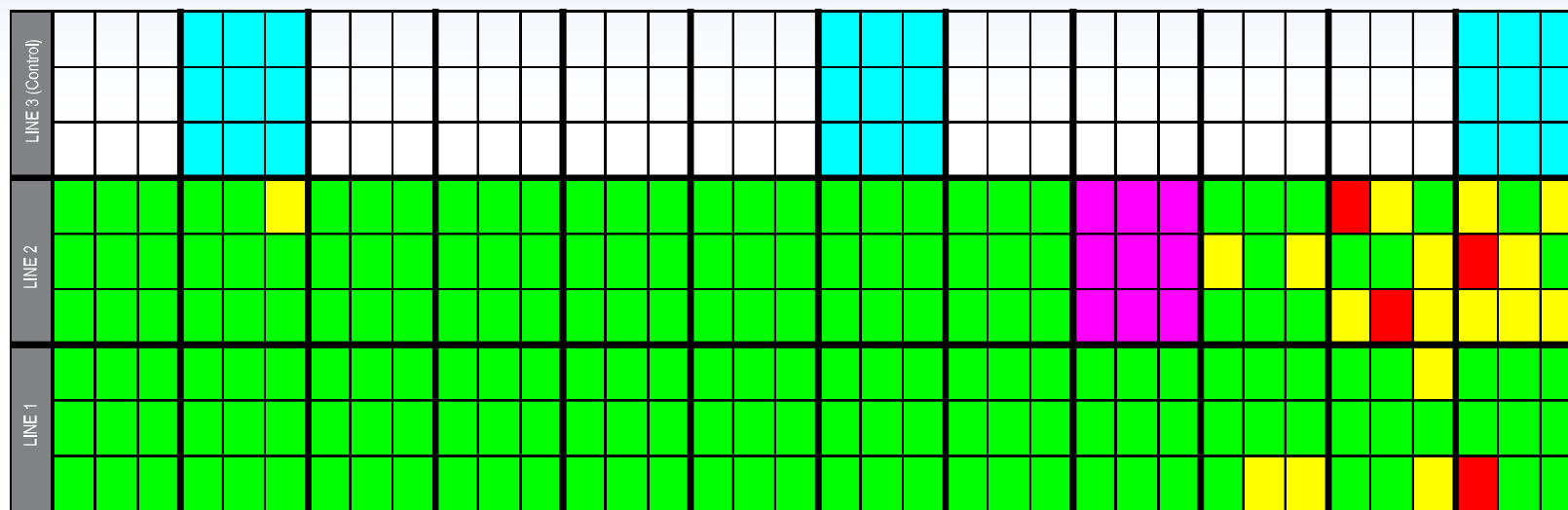
Total	24
Red	9
Yellow	12

Test Sites

216
12
52



Sublot 28-1



- Measured modulus is similar or higher than baseline modulus
- Measured modulus is somewhat less than baseline modulus
- Measured modulus is substantially less than baseline modulus
- Panels Removed and Replaced By Visual Inspection
- Baseline Panels (Control) - Acceptable

Panels (18.75'x 20)

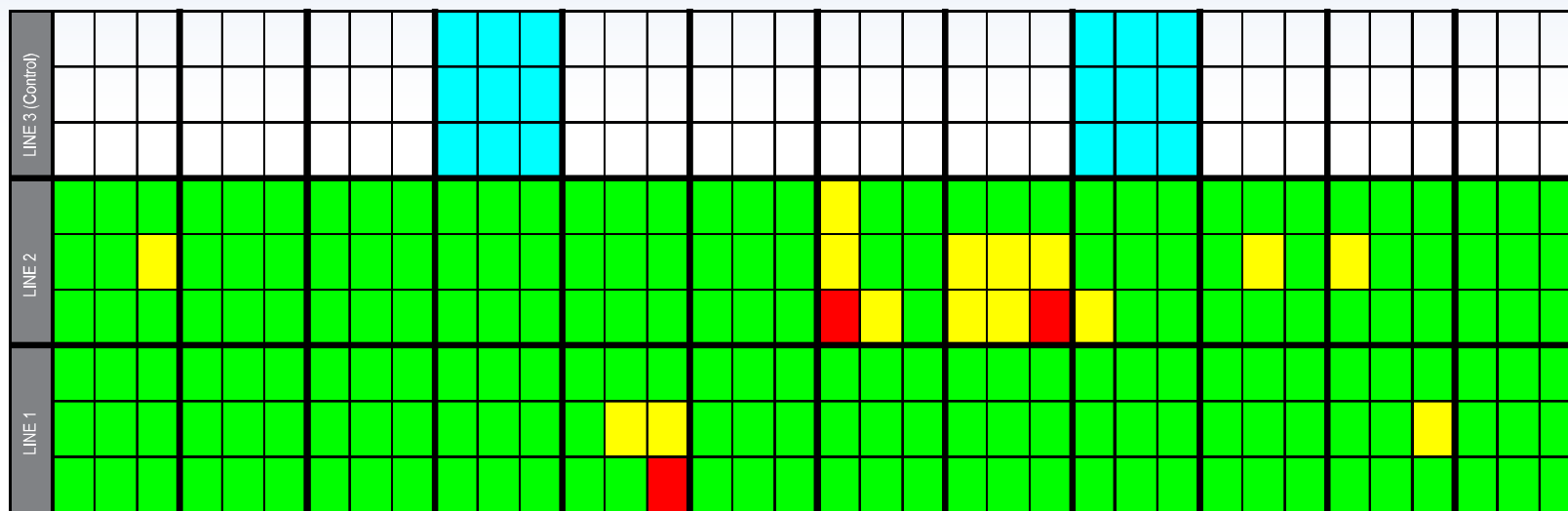
Total	23
Red	3
Yellow	3

Test Sites

207
4
16



Sublot 28-2



- Measured modulus is similar or higher than baseline modulus
- Measured modulus is somewhat less than baseline modulus
- Measured modulus is substantially less than baseline modulus
- Panels Removed and Replaced By Visual Inspection
- Baseline Panels (Control) - Acceptable

Panels (18.75'x 20')

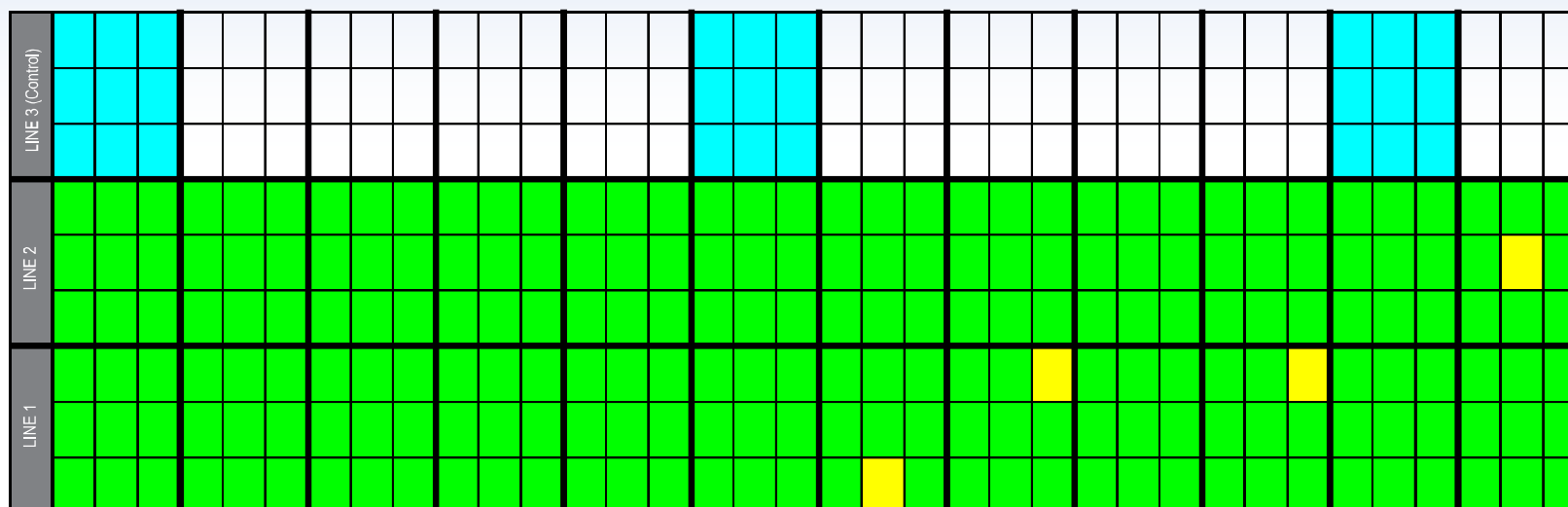
Total	24
Red	3
Yellow	5

Test Sites

216
3
15



Sublot 28-3



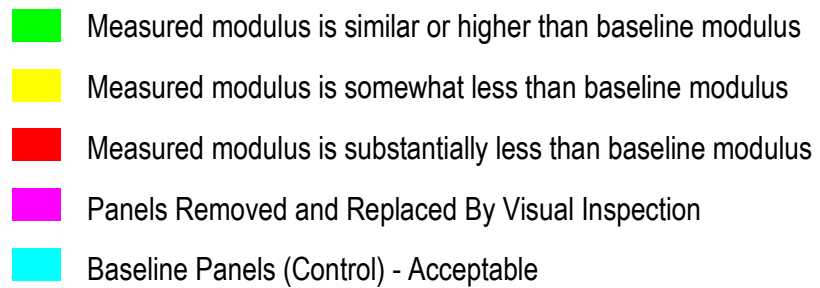
- Measured modulus is similar or higher than baseline modulus
- Measured modulus is somewhat less than baseline modulus
- Measured modulus is substantially less than baseline modulus
- Panels Removed and Replaced By Visual Inspection
- Baseline Panels (Control) - Acceptable

Panels (18.75'x 20')

Total	24
Red	0
Yellow	4

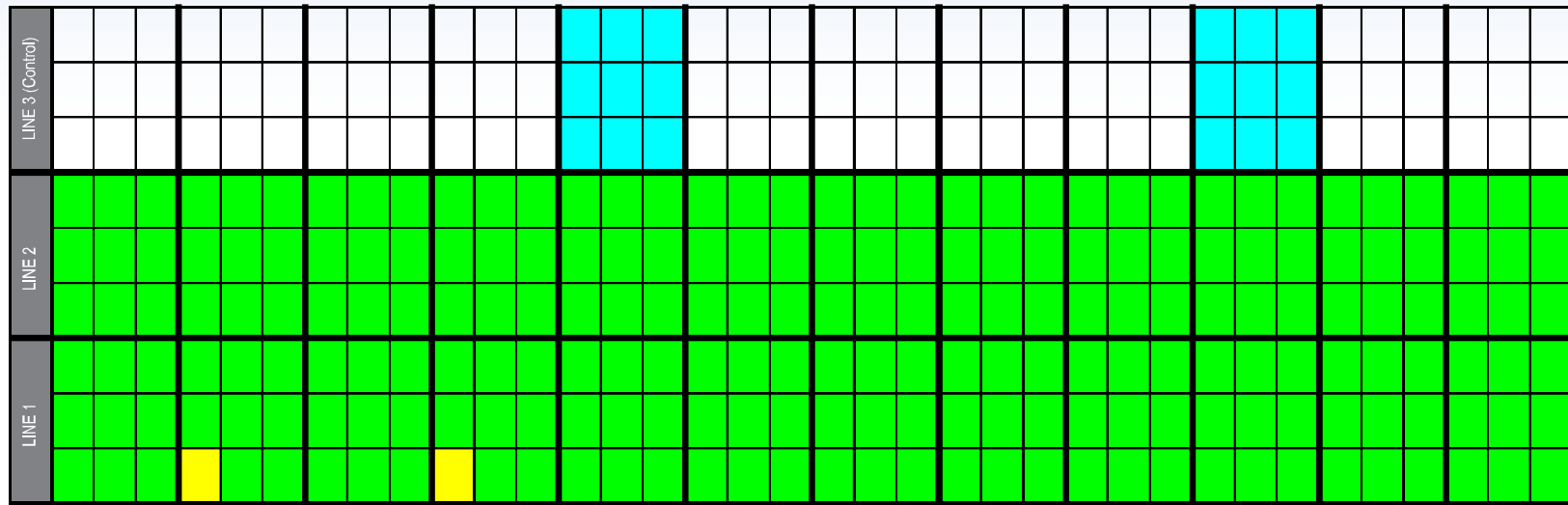
Test Sites

216
0
4





Sublot 29-1



- Measured modulus is similar or higher than baseline modulus
- Measured modulus is somewhat less than baseline modulus
- Measured modulus is substantially less than baseline modulus
- Panels Removed and Replaced By Visual Inspection
- Baseline Panels (Control) - Acceptable

Panels (18.75'x 20)

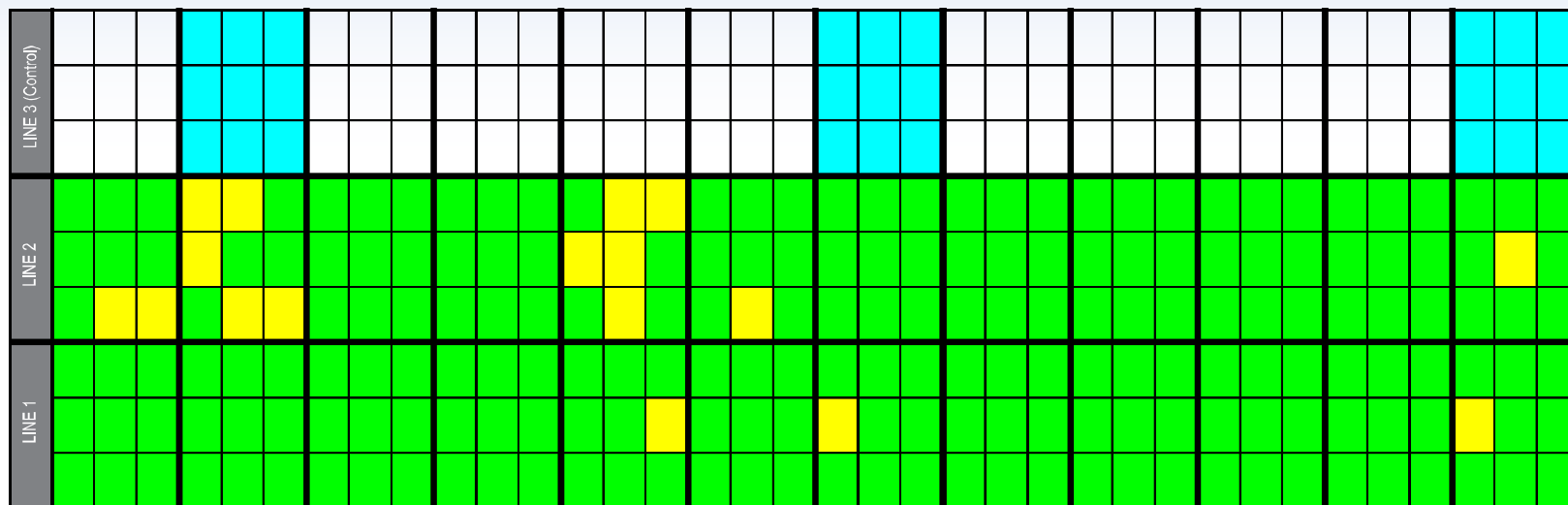
Total	24
Red	0
Yellow	2

Test Sites

216
0
2



Sublot 29-2



- Measured modulus is similar or higher than baseline modulus
- Measured modulus is somewhat less than baseline modulus
- Measured modulus is substantially less than baseline modulus
- Panels Removed and Replaced By Visual Inspection
- Baseline Panels (Control) - Acceptable

Panels (18.75'x 20')

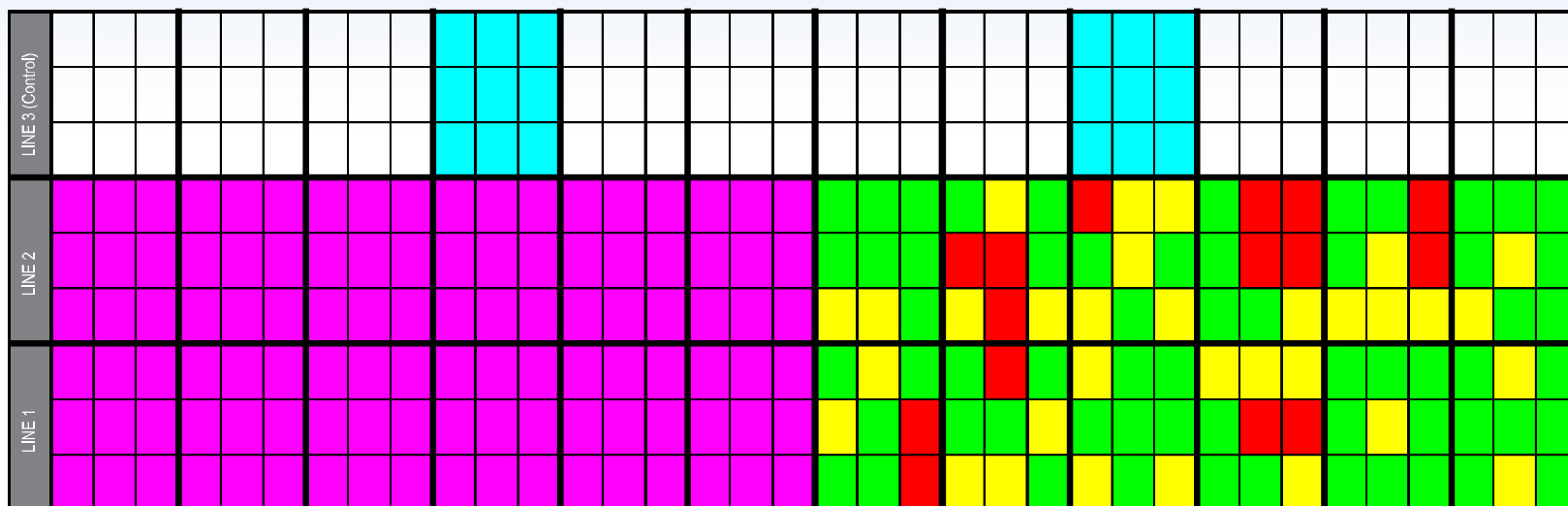
Total	24
Red	0
Yellow	8

Test Sites

216
0
17



Sublot 29-3



- Measured modulus is similar or higher than baseline modulus
- Measured modulus is somewhat less than baseline modulus
- Measured modulus is substantially less than baseline modulus
- Panels Removed and Replaced By Visual Inspection
- Baseline Panels (Control) - Acceptable

Panels (18.75'x 20')

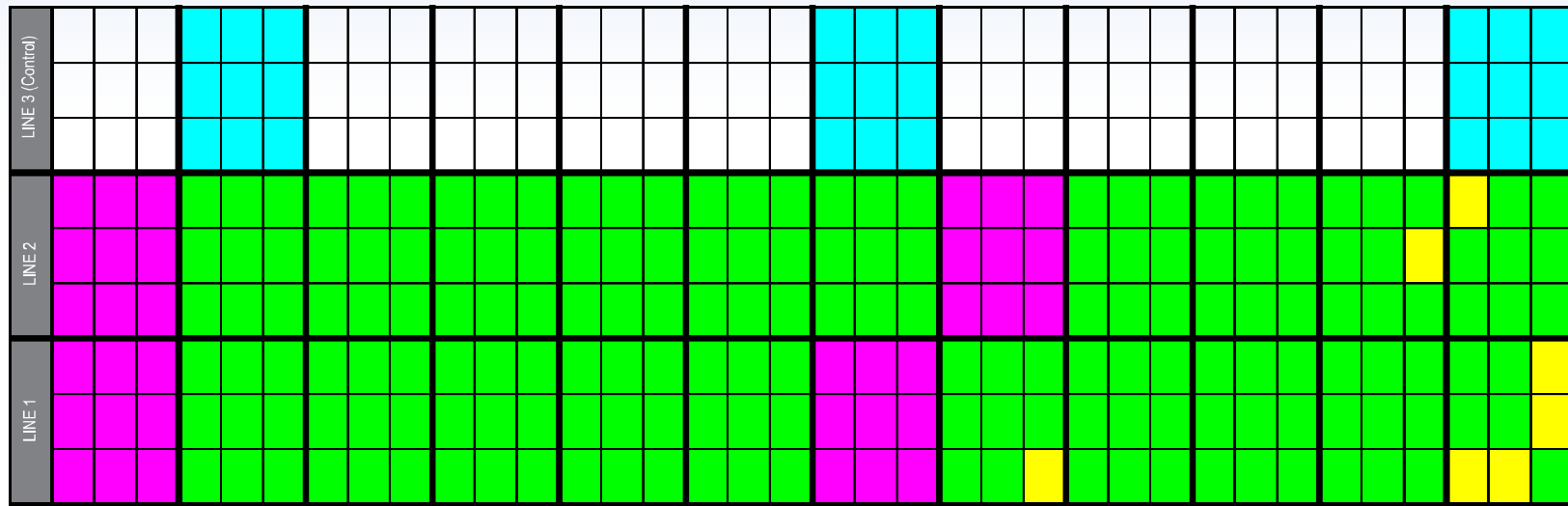
Total	12
Red	7
Yellow	5

Test Sites

108
15
32



Sublot 31-1



- Measured modulus is similar or higher than baseline modulus
- Measured modulus is somewhat less than baseline modulus
- Measured modulus is substantially less than baseline modulus
- Panels Removed and Replaced By Visual Inspection
- Baseline Panels (Control) - Acceptable

Panels (18.75' x 20')

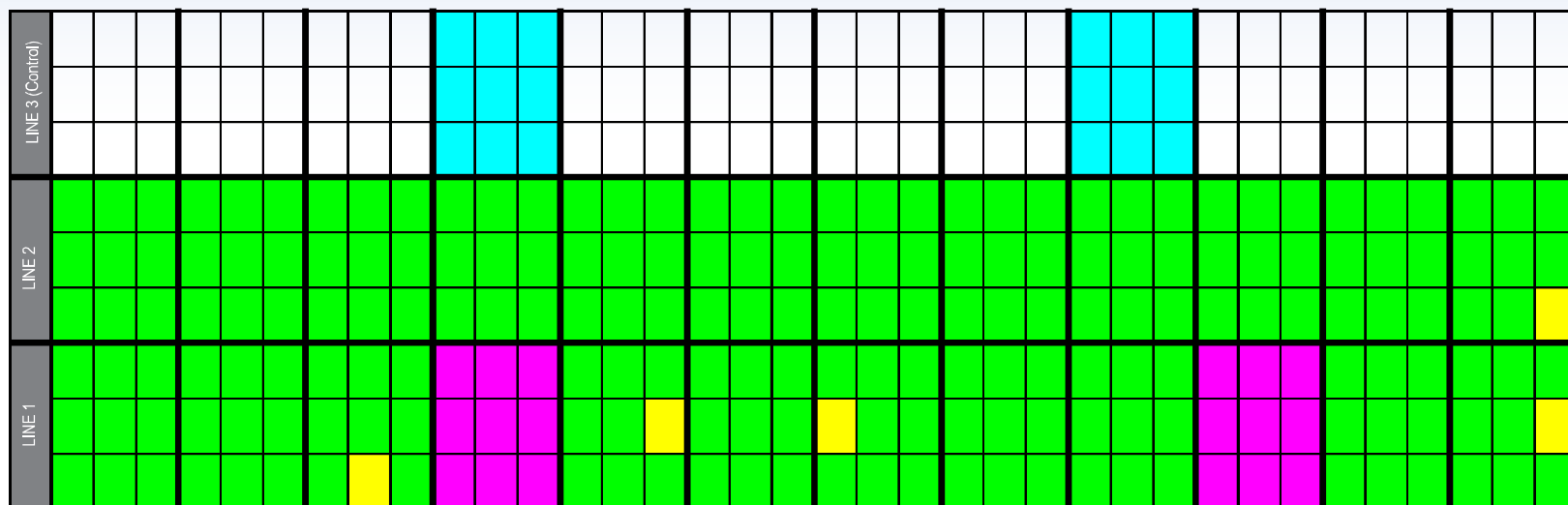
Total	20
Red	0
Yellow	4

Test Sites

180
0
7



Sublot 31-2



- Measured modulus is similar or higher than baseline modulus
- Measured modulus is somewhat less than baseline modulus
- Measured modulus is substantially less than baseline modulus
- Panels Removed and Replaced By Visual Inspection
- Baseline Panels (Control) - Acceptable

Panels (18.75'x 20')

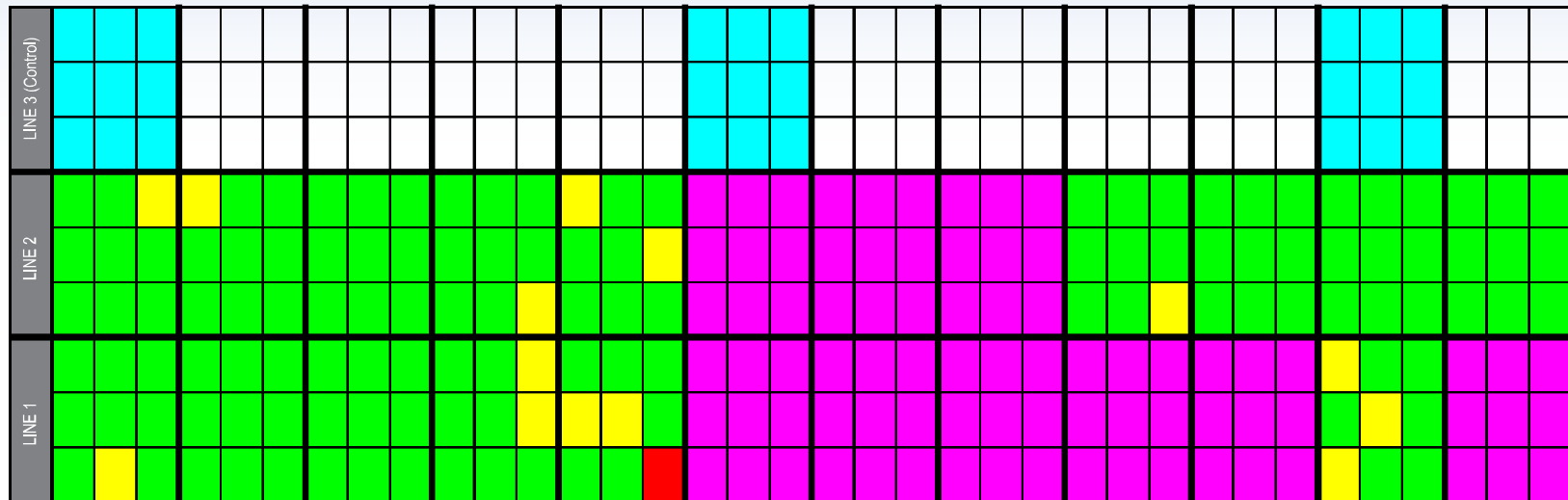
Total	22
Red	0
Yellow	5

Test Sites

198
0
5



Sublot 31-3



- Measured modulus is similar or higher than baseline modulus
- Measured modulus is somewhat less than baseline modulus
- Measured modulus is substantially less than baseline modulus
- Panels Removed and Replaced By Visual Inspection
- Baseline Panels (Control) - Acceptable

Panels (18.75'x 20')

Total	15
Red	1
Yellow	9

Test Sites

135
1
14



Summary of Results

Summary of Panels (18.75' x 20.00')
(Any panel with one or more red test site)

Sublot	# of Red	% Red	% Yellow
27-4	9	38	50
28-1	3	13	13
28-2	3	12	21
28-3	0	0	17
28-4	0	0	4
29-1	0	0	8
29-2	0	0	33
29-3	7	58	42
31-1	0	0	20
31-2	0	0	25
31-3	1	7	60
Total	23		

Marginal
Marginal



Summary of Testing

- **Total Test Sites: 2,126**
- **Red Test Sites: 35**
- **Total Panels: 236**
- **Red Panels: 23**
- **Sublots to Further Evaluate: 27-4 and 29-3**



Reliability-Based Assessment of Sublots

Lot	Sublot	PSPA Modulus, ksi		Probability of Moduli from Sublot Being Less than Baseline Slabs (P _F)	Statistical Interpretation (as compared to baseline slabs)
		Average	Standard Deviation		
Baseline		4838	248	N/A	
27	4	4714	247	64%	Lower Moduli
28	1	4964	245	36%	Higher Moduli
	2	4966	268	36%	Higher Moduli
	3	5088	253	24%	Higher Moduli
	4	5112	244	22%	Higher Moduli
29	1	5039	245	25%	Higher Moduli
	2	4877	176	45%	Similar
	3	4608	205	75%	Lower Moduli
31	1	4938	226	38%	Higher Moduli
	2	4937	202	38%	Higher Moduli
	3	4878	202	45%	Similar



Comparison of Thickness Cores To Field PSPA for Questionable Lines 1 and 2

Lot No.	Core No.	FFRC Modulus, ksi (CORES)				PSPA Modulus, ksi (FIELD)			
		Individual Core	N*	Average	COV (%)	N*	Average	COV (%)	Difference #
26*	26-1	5057	3	4929	4.9%	N/T	N/A	N/A	N/A
	26-2	4651							
	26-3	5080							
27	27-2	5021	3	4978	1.4%	216	4714	5.2%	5.3%
	27-3	5016							
	27-4	4898							
28	28-1	5146	4	5127	1.5%	855	5033	5.2%	1.8%
	28-2	5203							
	28-3	5018							
	28-4	5142							
29	29-1	4835	4	4787	9.2%	540	4888	5.2%	-2.1%
	29-2	5080							
	29-3	4151							
	29-4	5081							
30*	31-1	4716	3	4980	5.0%	513	4922	4.4%	1.2%
	31-2	5019							
	31-3	5207							

* Not in Our Study, But Cores Available to Test



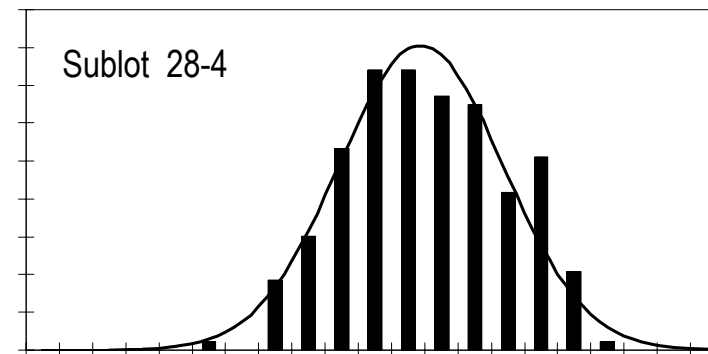
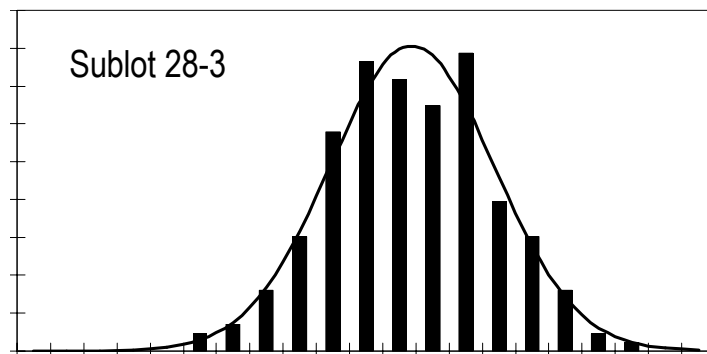
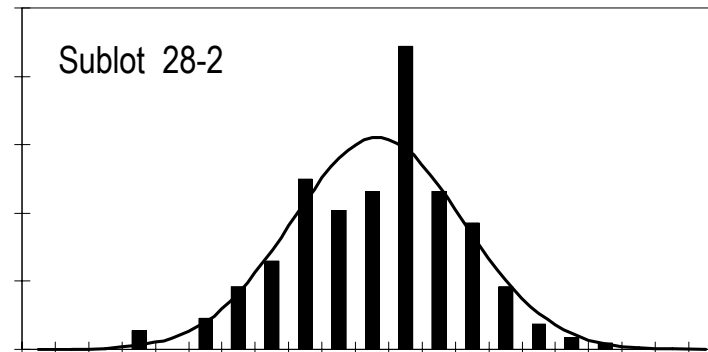
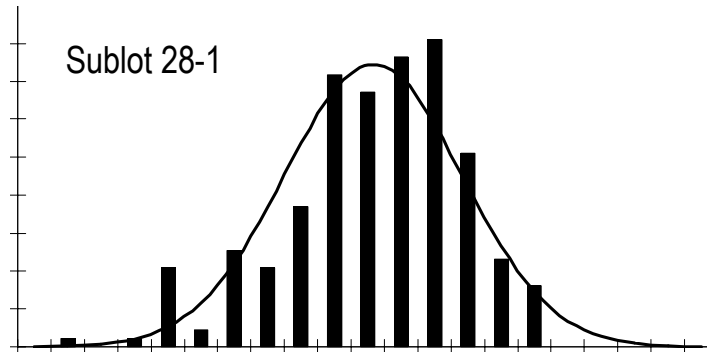
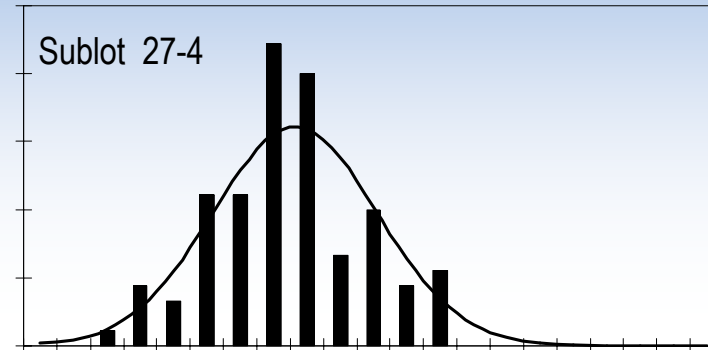
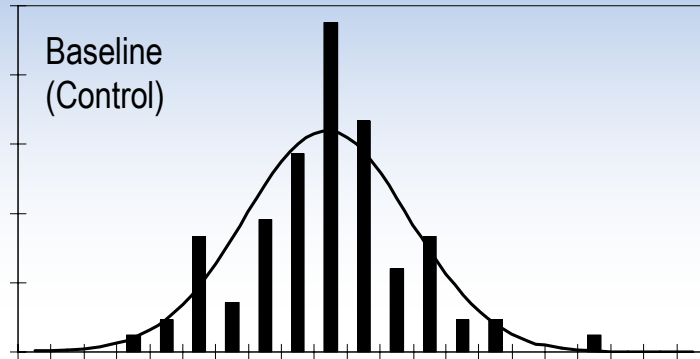
Comparison of the Thickness Cores to Field PSPA for Baseline (Control) Line 3

Lot No.	Core No.	FFRC Mod lus, ksi (LAB)				PSPA Modulus, ksi (FIELD)			
		Individual Core	N*	Average	COV (%)	N*	Average	COV (%)	Difference [#]
48*	48-1	5022	4	4976	3.5%	9	4767	4.1%	4.2%
	48-2	4717							
	48-3	5084							
	48-4	5081							
49*	49-1	4715	4	4822	5.8%	30	4929	5.9%	-2.2%
	49-2	4475							
	49-3	5082							
	49-4	5017							
50*	50-1	4894	4	4942	2.8%	21	4675	3.8%	5.4%
	50-2	5017							
	50-3	4775							
	50-4	5083							
51*	51-1	5022	4	4851	2.8%	N/A	N/A	N/A	N/A
	51-2	4896							
	51-3	4713							
	51-4	4775							
52*	52-1	4655	2	5026	10.4%	24	4893	3.8%	2.6%
	52-3	5397							

*Not in Our Study, But Cores Available to Test

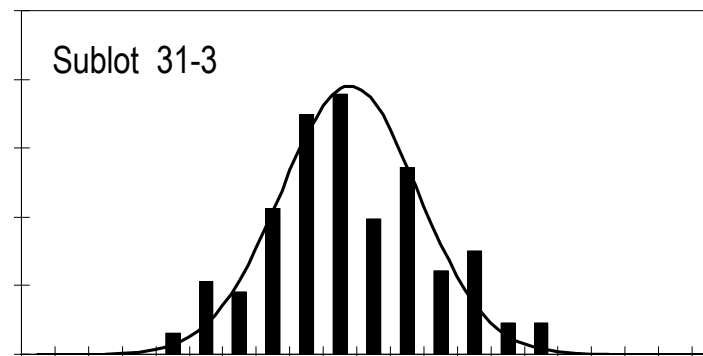
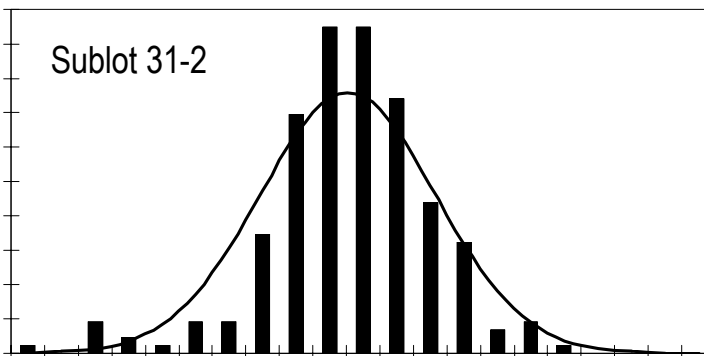
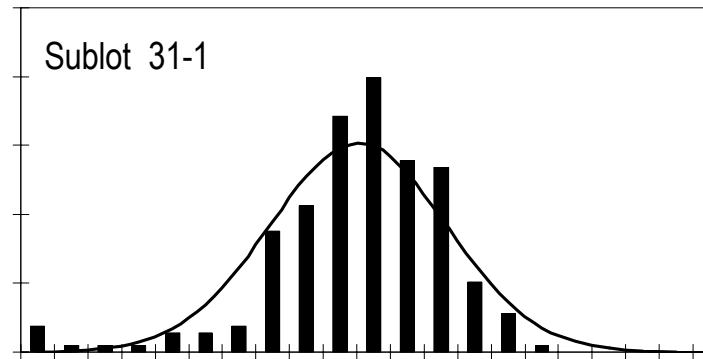
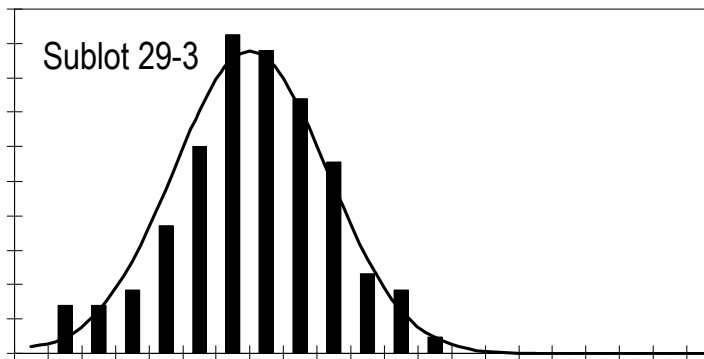
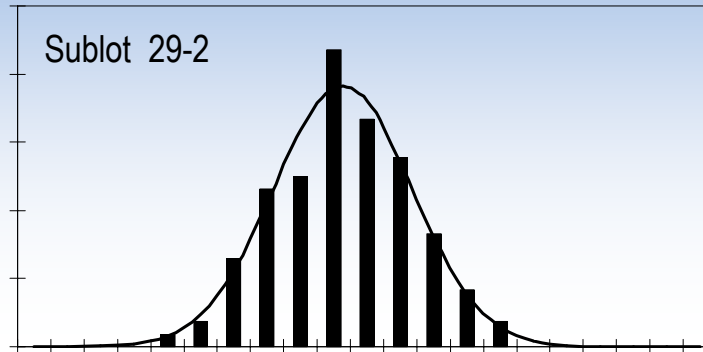
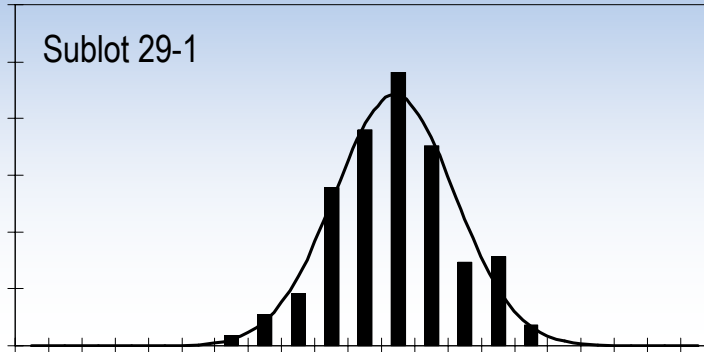


Distribution of TEST SITE Seismic Modulus for Each Sub Lot





Distribution of TEST SITE Seismic Modulus for Each Sub Lot (Cont)



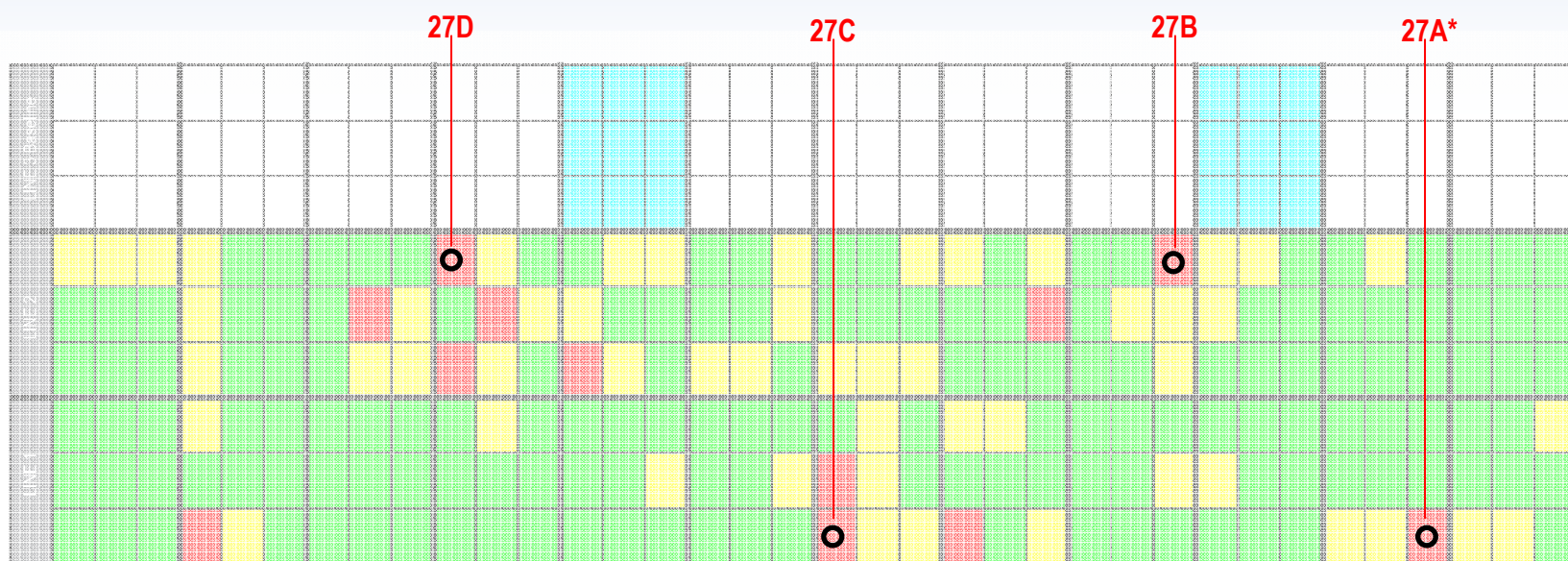


Further Evaluation of Sublots 27-4, 28-1, 28-2 and 29-3

- **Extracted 16 new cores from questionable panels**
- **Used Petrographic analysis to evaluate new cores extracted**
- **4 Control, 4 from 27-4, 2 from 28-1, 1 from 28-2 and 5 from 29-3**
- **Accomplished 3 tasks on cores: Visual Inspection, Air Void System Analysis & Petrographic Analysis**

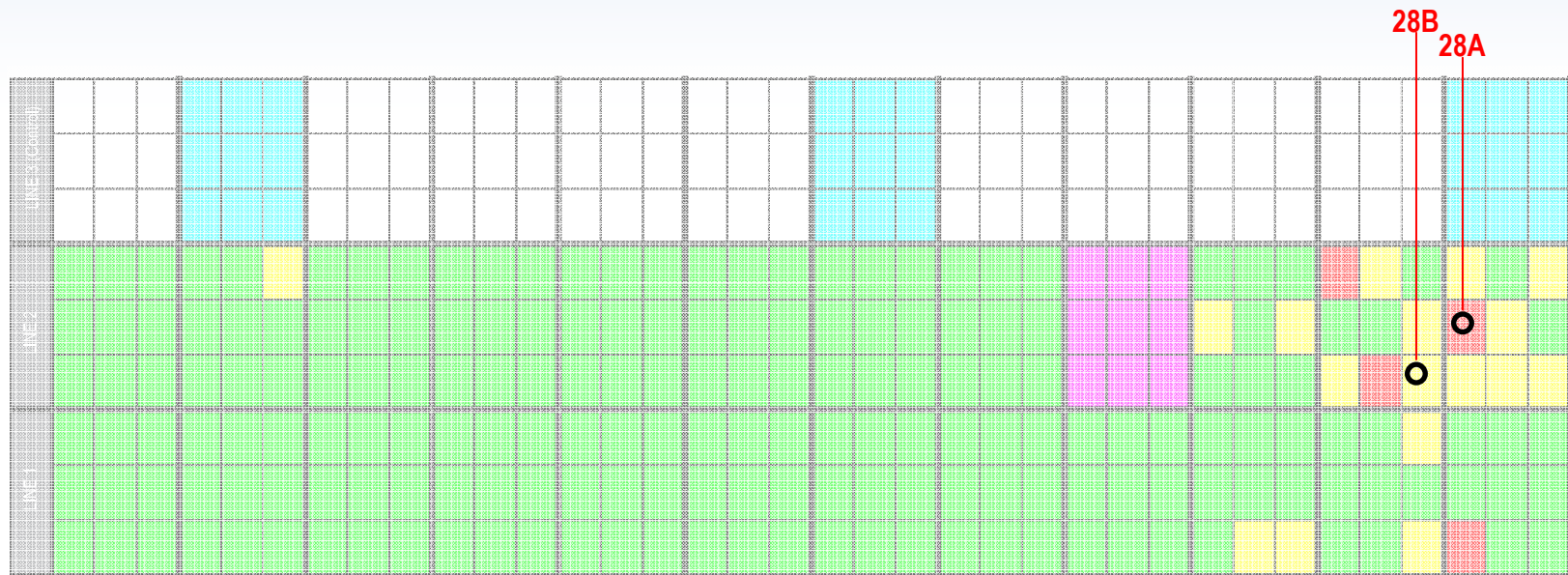


Core Locations for Sublot 27-4



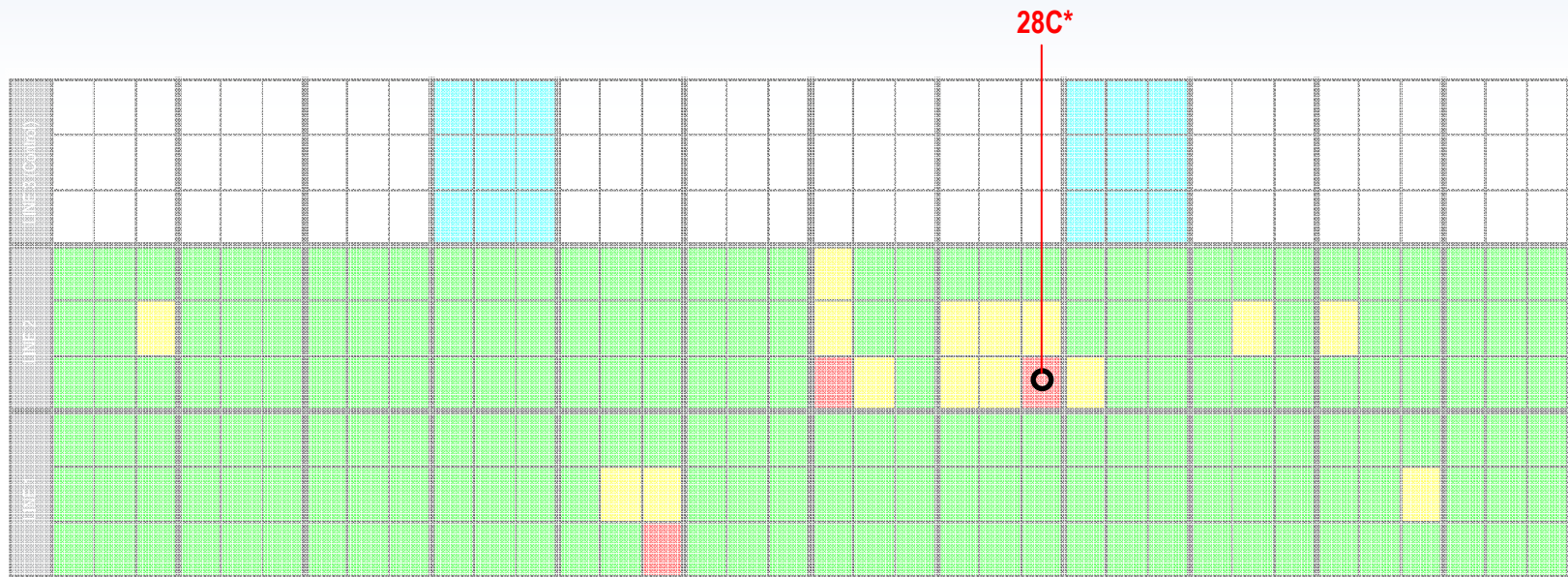


Core Locations for Sublot 28-1



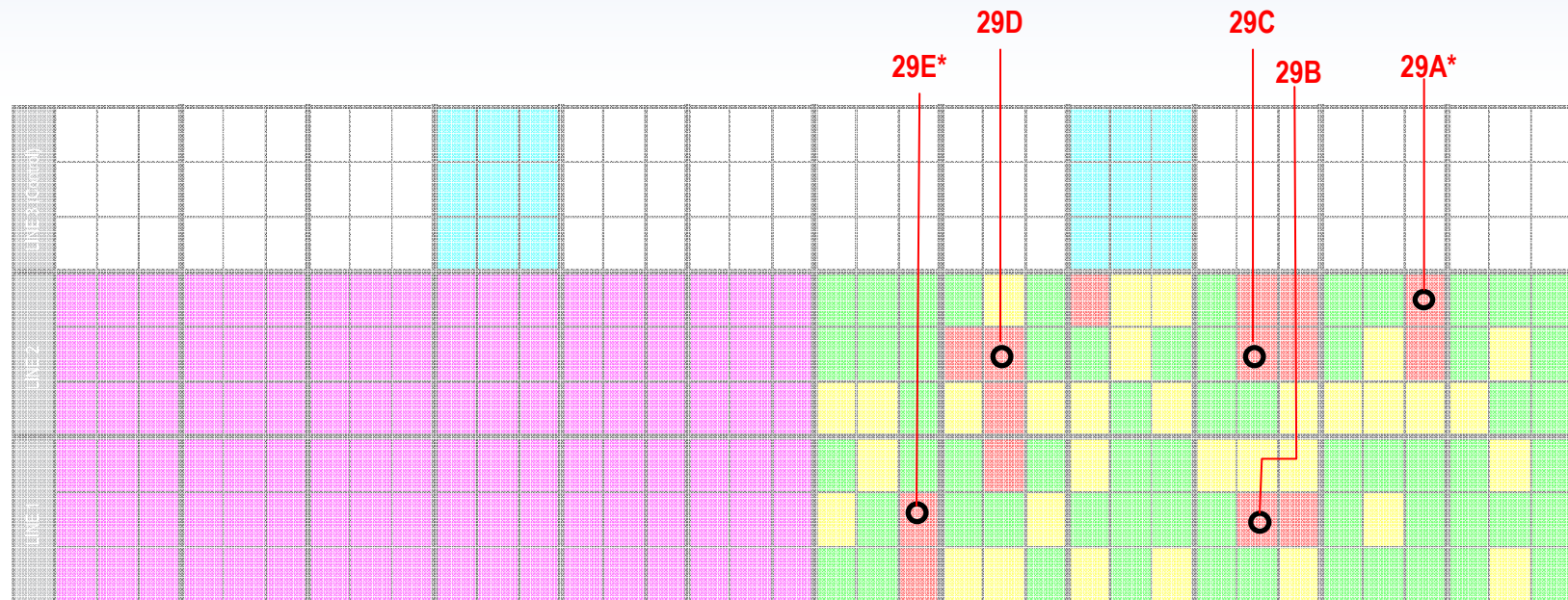


Core Locations for Sublot 28-2





Core Locations for Sublot 29-3





Petrographic Results

- 5 cores analyzed for air void and petrographic
- All cores air content 6 +/- 1.5%
- All cores spacing factor less 0.008", met ASTM and is most significant for durability
- 2 have paste to air ratio less than 4, ASTM range 4 to 10
- Specific surface of 3 is less than ASTM range
- 2 have fly ash contents significantly higher than other cores



Petrographic Conclusions

- Concrete is sound and intact
- No evidence of major flaws
- Pavement texture is all intact
- Likely that concrete durable to freeze-thaw
- No evidence of ASR



Owner's Decision

- **Accept PSPA results of adequate strength for 9 of the 11 sublots (not 27-4 and 29-3)**
- **Accept Petrographic results for Sublots 27-4 and 29-3 and verified 28-1 and 28-2 could remain**
- **Allowed all panels in the 11 sublots that were tested, to remain in-place**
- **Contractor received no payment for the 23 panels with 1 or more “red” test sites**



Conclusions

- **PSPA testing was successful in verifying the PCC strength**
- **PSPA identified panels/test sites for additional testing**
- **Petrographic analysis confirmed the PSPA results**
- **Petrographic analysis verified PCC could be left in-place**



- **QUESTIONS?**